ATTACHMENT 3

FCC Progress Report
February 8, 2017

Federal Communications Commission
Experimental Licensing Branch
MS 1300E1
445 12th Street SW
Washington, DC 20554

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Background

Broadband is a critical part of our nation's infrastructure and it is the building block that is powering our economy, creating jobs and educational opportunities in communities across our country. Broadband access can mean the difference between finding a job and remaining unemployed, or a child completing his or her homework or going to school empty-handed. Unfortunately, access to a fast, reliable internet connection is not universal and the digital divide that results is hamstringing families and communities.

However, emerging '5G' technologies offer an opportunity to use previously untapped millimeter wave spectrum to deploy next generation wireless technologies that have the potential to not just narrow the digital divide, but close it all together. 5G represents an opportunity to use millimeter wave spectrum in new and innovative ways, providing another choice in connectivity for millions of people and small businesses, in both urban and rural areas. These new millimeter wave technologies also have the ability to help speed the development of Gigabit Opportunity Zones, areas that serve as magnets for start-ups and other businesses that require high bandwidth capacity.

Starry, Inc., is a Boston- and New York-based technology company that is using millimeter waves to re-imagine last-mile broadband access, as an alternative to fixed wireline broadband. Starry has developed and deployed proprietary fixed '5G' wireless technology that utilizes millimeter wave spectrum to connect consumers to high speed, gigabit-capable wireless broadband. Starry's ability to provide wireless last-mile connectivity, without the need for direct line-of-sight, offers a major advantage over traditional fixed-wireline providers, enabling Starry to offer broadband access at a fraction of the cost of current providers.

Starry was founded in late 2014 as "Project Decibel" by a team of talented hardware, software and RF engineers who began work on developing millimeter wave technology that could deliver reliable, gigabit-capable connections in dense urban environments. After 14 months of research and development, the Starry team created and built a full-stack technology consisting of a network-node (Starry Beam), a home receiver (Starry Point) and a Wi-Fi access point (Starry Station). In 2016, Starry sought and was granted by the FCC experimental market test authority licenses for the 37.0 to 38.6 GHz bands in 18 markets.

Starry has performed extensive tests to characterize the performance of these bands in an urban environment and, in late summer of 2016, entered into a closed consumer beta in the Boston area.

As required by the grant of this license, Starry has prepared the following report which provides the Commission with a window into our learning over the past year.

Starry's Technology Approach

Starry's technical architecture include three key components: Starry Beam, the network-node, which communicates using millimeter wave spectrum to Starry Point, the at-premise transceiver, which communicates to Starry Station, the in-home WiFi hub.

Starry Beam utilizes an active phased array for Point-to-Multipoint consumer internet access. By taking the innovative approach of utilizing available 802.11ac baseband technology in our infrastructure, Starry is able to marry these two technological approaches to create a highly efficient and extremely low cost internet delivery system using millimeter waves. This is a hybrid approach to beamforming which is especially practical for millimeter waves due to the small sizes of antennas. Designed and developed in-house, Starry's full-stack technology approach enables the company to have transparency into the performance and stability of the Starry Internet service, from node to home, ensuring a better overall quality of customer care.

Starry's key technology innovations include:

- Innovative approach to baseband radios in infrastructure: utilization of 802.11ac radios with 5 Gbps per beam sector with MU-MIMO (15 Gbps per site) covering 1.5 km in near-line-of-sight conditions and 1 km in non-line-of-sight conditions.
- Ability to transition to 802.11ax which will enable ~45-50 Gbps per site.
- Deployment of active phased array for consumer internet.
- Hybrid multi-beamformed Rx & Tx.
- Starry Beams cover 120-degree sectors with an effective range up to 1.5 km, after taking into account rain fade, foliage and reflections. Free space range in line-of-sight conditions is approximately 10 km.

Field Tests & Results

Since early 2016, Starry has been in the field, testing and characterizing the performance of the 39 GHz band in the Boston Area (in these tests, Starry used 160 MHz channels within the 38.2-38.6 GHz band). Our experimental testing was designed to characterize performance between Starry Beam and Starry Point. At the outset, we hoped to learn more about the behavior and propagation of this band in an urban topography and also the impact of scattering on throughput.

Impact of Scattering

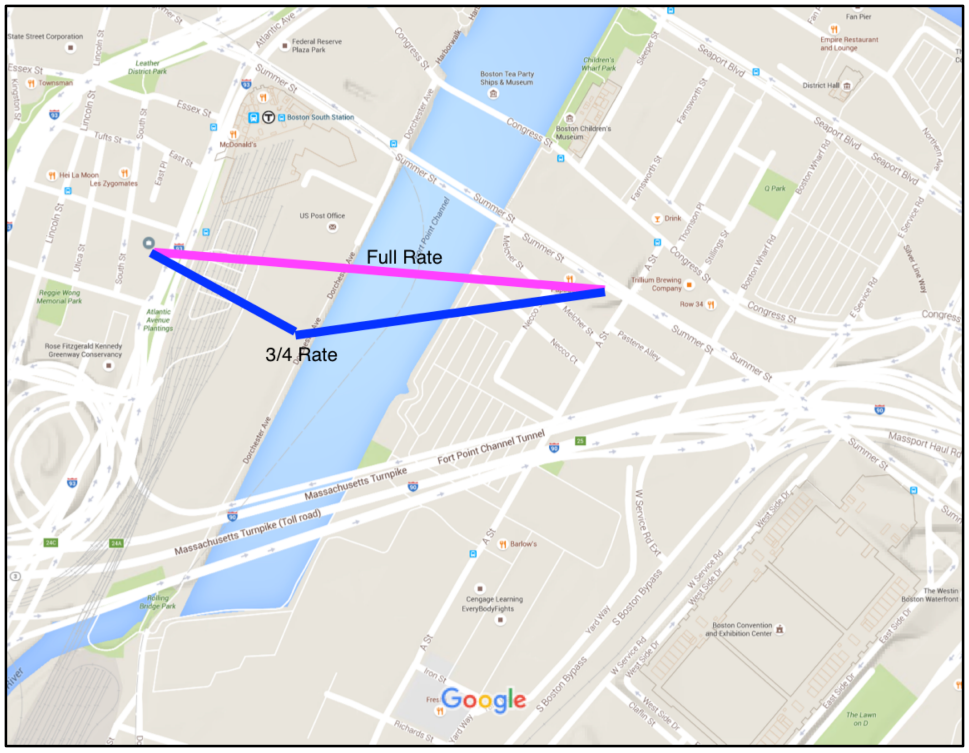


Figure 1. Impact of scattering in Azimuth (3/4 rate observed with 1 -3 reflections)

WHAT WE LEARNED: THERE ARE SOME IMPACTS OF SCATTERING ON MIMO

- Millimeter wave scattering of the WiFi OFDM signals are similar enough to 5 GHz scattering to function well with existing receivers.
- Ground reflections and building reflections fill out coverage.
- Measurements show the MIMO working well on reflections.

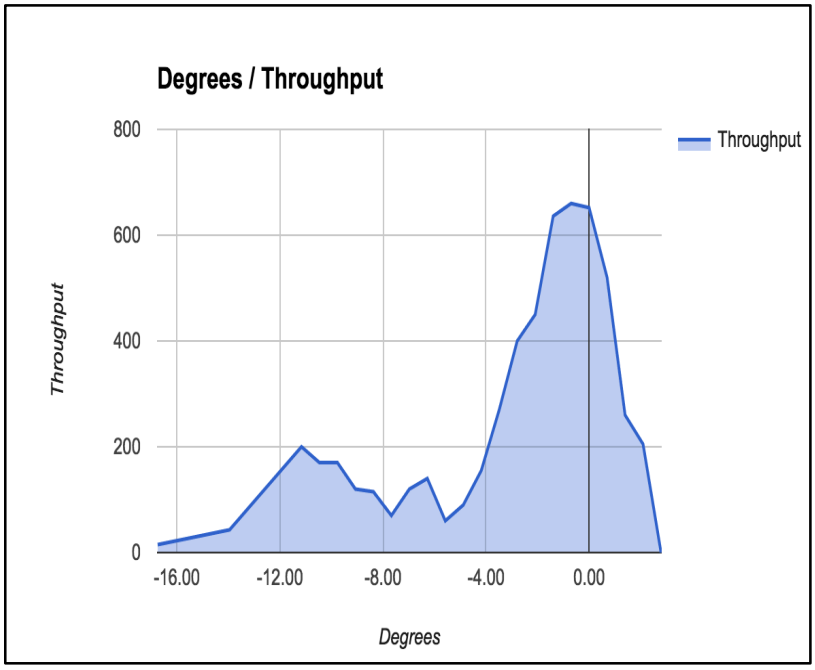
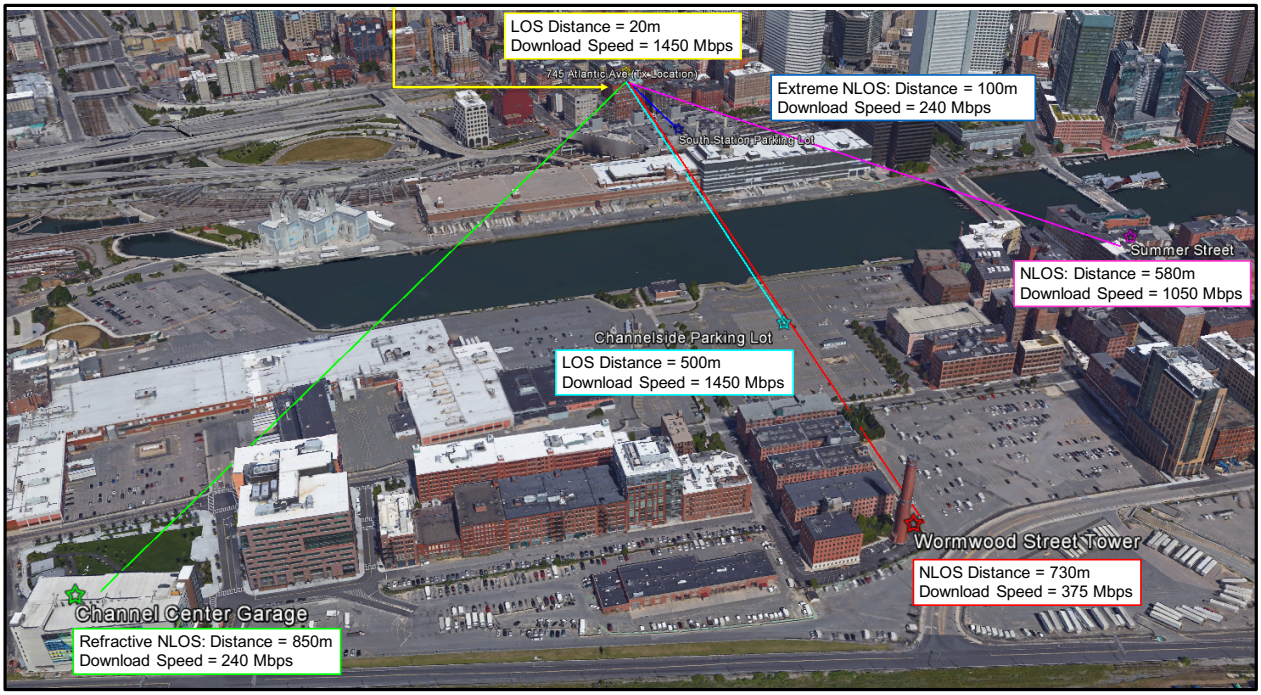


Figure 2. Impact of scattering towards ground reflections (negative angles). (Test case shown, reduced bandwidth & reduced spatial streams)

TCP Download Speeds Achieved*

Starry Beam Test Location: 745 Atlantic Avenue



**Using 160 MHz channels at 256 QAM, MCS5 to MCS9 two spatial streams. Target transceiver at 10' elevation from ground. Key: LOS-Line of Sight; NLOS-near Line of Sight (outside the first Fresnel zone); Extreme NLOS purely working on multiple reflections).*

Link Budget for One Tested Configuration
Starry Beam to Starry Point

Distance (m)	815	
Path Loss (dB)	72	
Equipment Parameters	**Starry Beam**	**Starry Point A**
Radio equipment	Starry Beam	Starry Point
Tx antenna	Integral Active Phased Array	Passive Phased Array
Tx antenna gain (dB)	24	24
Tx Polarizer Loss (dB)	1	0
Rx antenna	Integral Active Phased Array	Passive Phased Array
Rx antenna gain (dB)	24	24
Rx Polarizer loss (dB)	1	-
Transmitter		
Transmit power per antenna port (dBm)	27	19
EIRP (dBm)	52	42.5
Receiver		
Noise figure (dB)	8.5	6
Point to Point equipment settings		
Channel Bandwidth (MHz)	160	
Channel	1	
Polarization	Horizontal & Vertical	
Capacity	**Starry Beam → Point A**	**Point A → Starry Beam**
Results		
Rx power (dBm)	-50	-60
Mean SINR (dB)	36	21
SINR with availability margin (dB)	34	19
Transmission mode	Starry 2 x 2 Radio	Starry 2 x 2 Radio
MCS	MCS 9	MCS 7
TCP Throughput (Mbps)	1400	1100

Beta Deployment

In late summer 2016, Starry launched a closed beta in the Boston area to test service to consumer households. Starry's beta targets areas where the population density is a minimum of 1,000 homes per square mile. Starry's beta sought to build on and further confirm the results of the experimental data gathered in the previous months. Key goals of the beta, in its earliest stages, were to understand in more detail the impacts of weather and foliage (particularly, as seasons change) and urban topography (building reflections) on service to a residential premise. Additionally, the closed beta is enabling Starry to stress-test and stabilize the service further.

Presently the Starry Beta installation provides coverage in parts Charlestown, Cambridge and Somerville, Massachusetts, passing approximately 10,000 homes.

Starry intends to expand its beta in Boston in the first and second quarters of 2017. Additionally, Starry will begin build out of additional beta markets in the third and fourth quarters of 2017. Before the end of the year 2017, Starry anticipates passing more than 200,000 homes in the greater Boston area and over 400,000 homes in the initial build out of the remaining markets. Starry has demonstrated a very low cost build model (under $25 per home passed in metropolitan markets) for the network, which bodes well for a competitive alternative to expensive wireline-build models currently in vogue.

Starry has also initiated pricing tests with consumers. The data is preliminary and not appropriate for publication at this time.

Conclusion

Millimeter wave spectrum offers enormous opportunity to expand broadband access and competition. While research in and development of equipment for these bands is in its infancy, Starry has the ability to put these bands to work today. The opportunity to test, characterize and provide service in these bands through the FCC's market test authority license provides valuable data and the validation necessary to continue our investment in developing the next generation of '5G' communications technology.